Towards Low Energy Mobility Using Light and Ultralight Electric Vehicles.

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Part 1
General view:
Conventional Vehicles compared with electric and light electric vehicles

EELAB

History

"la jamais contente" 1899
Camille Jenatzy Belgian
electric, ± 1400kg
First 105km/h ,at Achères France

- 9 parts of rivetted partinium: Aluminium Tungsten alloy, laminated with magnesium
- DC drive without differential
- Pb accumulators 100x2V (for 2000m long)
- No steering wheel, but 2 handles
- No mechanic brakes

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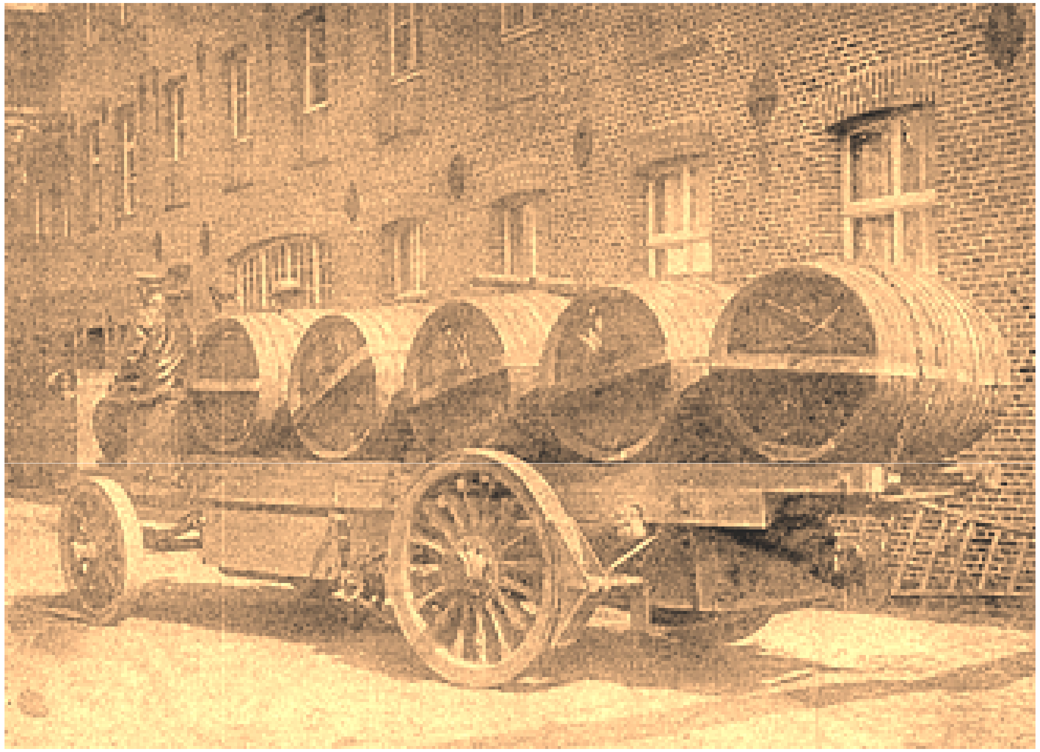
History



Batteries at the bottom,

Chain transmission

Wooden frame, chain reduction.

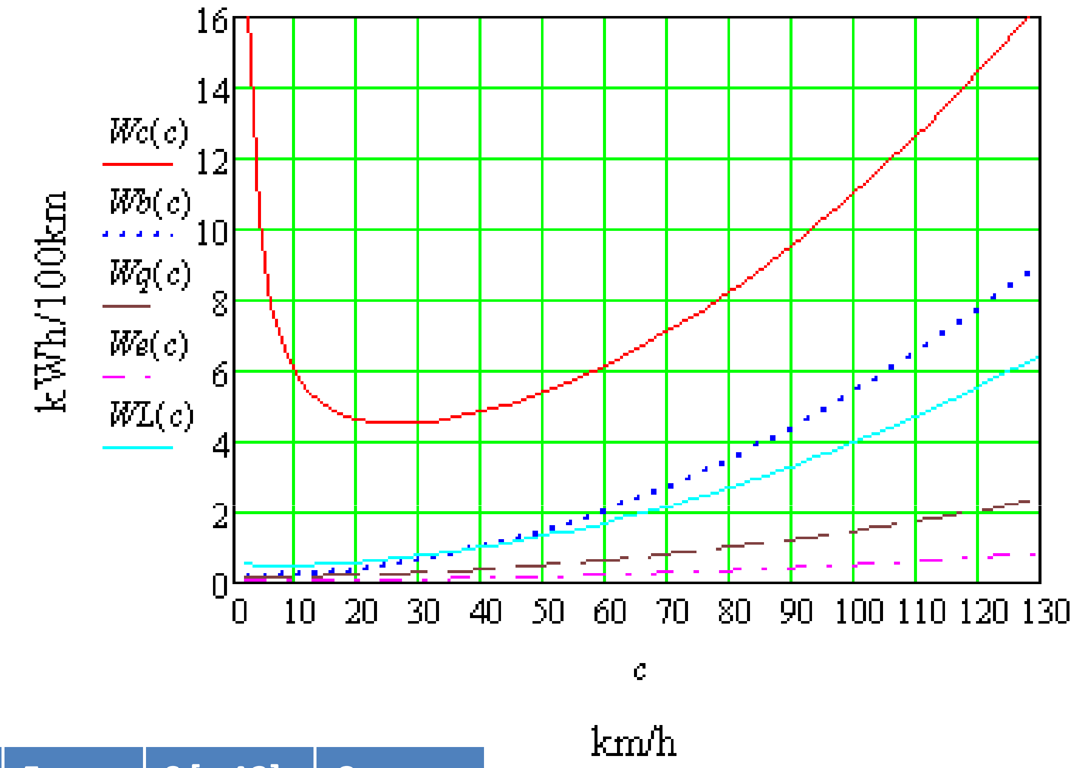
“Natural fibre”

“<- Camille Jenatzy Belgian
electric “Beer truck” Wieze, about 1905
Wieze-Brussels at 5km/h

kWh/100km mechanical need?

Energy 5 Hogent

Quest Velomobiel



type	curve	M [kg] Curb + user	Fc [./.]	S [m^2]	Cx
Today car	Wc	1200+100	0.008	2	0.3
E-bike	Wb	25+85	0.006	0.5	0.8
Quest	Wq	39+85	0.005	0.22	0.47
Energy5	We	60+55	0.002	0.136	0.254
Elbev	WL	100+100	0.008	0.9	0.3

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“Elbev”
Ecologic low budget electric vehicle

Ultralight electric vehicle
Low budget development: Partners: Ugent EELAB – Hogent Electromechanics

Target Specicifations
- Single person (for the moment)
- about 100 kg
- Three wheel: two driven front wheels, one back
- Speed range 70-80km/h
- Gradability ≥ 20%
- Acceleration: about 0-50km/h in 8 seconds
- Consumption 2kWh/100km country side, 3kWh/100km city
- Drive: front wheel high efficiency BLDC 2x4kW peak , motor weight 1.6 kg/motor
- Elements as safety, avoiding 12V battery….
- 2 times 48V 20Ah Li-ion in series (one can add more)

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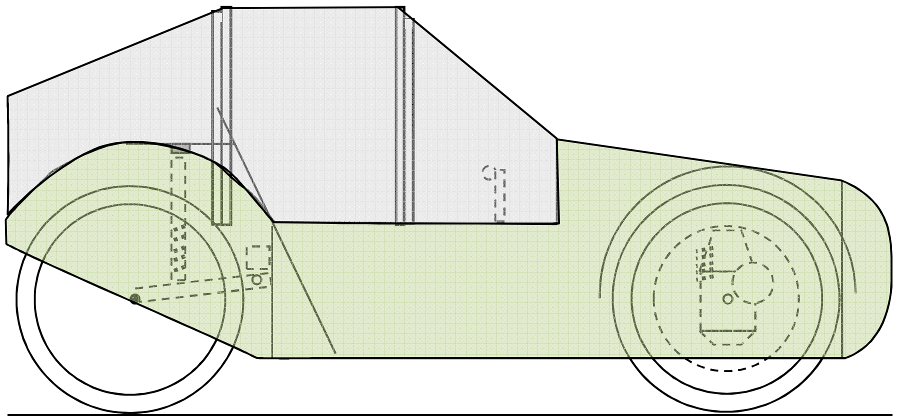
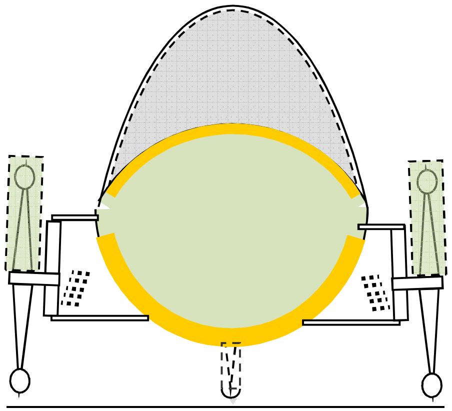
Elbev concept

Ecologic low budget electric vehicle

EELAB Ugent original concept; project with Hogent





Elbev: impression, intended for 0.5m² cross section,
(but it became 0.9m² with more space)

Electric vehicles

	kWh/100km At wall plug	Curb weight kg
Electric bike	1 (+0.5 human)	20…30kg
elbev	2-3 (3 city)	80…100
Light high efficiency 4 person	10	800
Normal With high efficiency drive	15	1300
Heavy With normal efficiency	20	1800
Electric SUV	25	>2000

Ultralight and light vehicles

As far as possible, the vehicle should weight
less or equal to the usually transported goods

	Ultralight [kg/person]	Light [kg/person]	Normal [kg/person]
Electric bike Weight/person	20	25	30
Non-covered 3-4 wheel Electric vehicle	<60	<120	200
Covered 3-4 wheel	<100	<200	300

E-Bikes satisfy perfectly, but are non covered (rain and cold)
Single or two person vehicles, 3,4,5,6 person?
Why not apply the kg/person gradually also to public transport?

Ratio Electric / fuel engines?

- 1 liter of gasoil Diesel = 35.94 MJ/liter

  (=42.91MJ/kg LHV density 837 kg/m^3)

  http://www.academia.edu/1073990/The_Energy_and_Fuel_Data_Sheet
- 1 liter of Gasoline (Benzine)= 32.7 MJ/liter

  44.15MJ/kg LHV density 741 g/m^3 ,

  http://www.highlandfuels.co.uk/downloads/Esso_Super_Plus_ULS_Petrol_Spec_Sheet.pdf
- Electricity 3,6MJ/kWh
- For non-specialists:

  1liter of fuel ≅ 1m^3 of natural gas ≅ 10kWh

  Gasoline 0.18 and diesel fuel in Belgium ≅ 1.45 Euro/kWh heat

  Night tariff electricity ≅ 0.17Euro/kWh, so similar for heat.

  So efficiencies can be directly compared So

More: http://en.wikipedia.org/wiki/Fuel_efficiency

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Efficiency of conventional engines?

- Combustion engines in cars,

  typical maximum 35% for diesel, 30% for gasoline
- Practically, in actual efficient cars, (air + tire friction)/fuel

  14% for a diesel, (5 liter/100km,2% equivalent slope, 1300kg)

  0.02*9.81*1300*10^5/(35.94*5)=14.2%

  13% for gasoline (5.5 liter/100km, 2% equivalent slope, 1050kg)

  0.02*9.81*1200*10^5/(32.7*5.5)=13.1%
- Mobility efficiency?

  x usefull weight/total weight

  For one person in a car: 1.09% diesel, 1.09% gasoline so typical 1.1%
- Ecologic efficiency?

  Even a factor 2 lower due to manufacturing energy

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Efficiency of Electric Cars?

- Maximum efficiency of charger, battery, converter, motor= 95x90x96x90 = 74%
- Practically in real conditions 50-60% in high efficiency drives, <40% in average efficiency drives.
- Mobility efficiency;

  Normal for 50% and 100kg usefull on 1400kg total 3.57%

  Ultralight for 60% and ultralight 100kg on 200kg total 30%

  Ecologic: probably factor 3 lower if manufacturing energy is considered
- Fuel efficiency of electricity?

  1kWh electricity is traditionally considered be generated by 40% efficiency

  But a combined cycle at noght: 59%, with 10% transmission loss =>53.1%?

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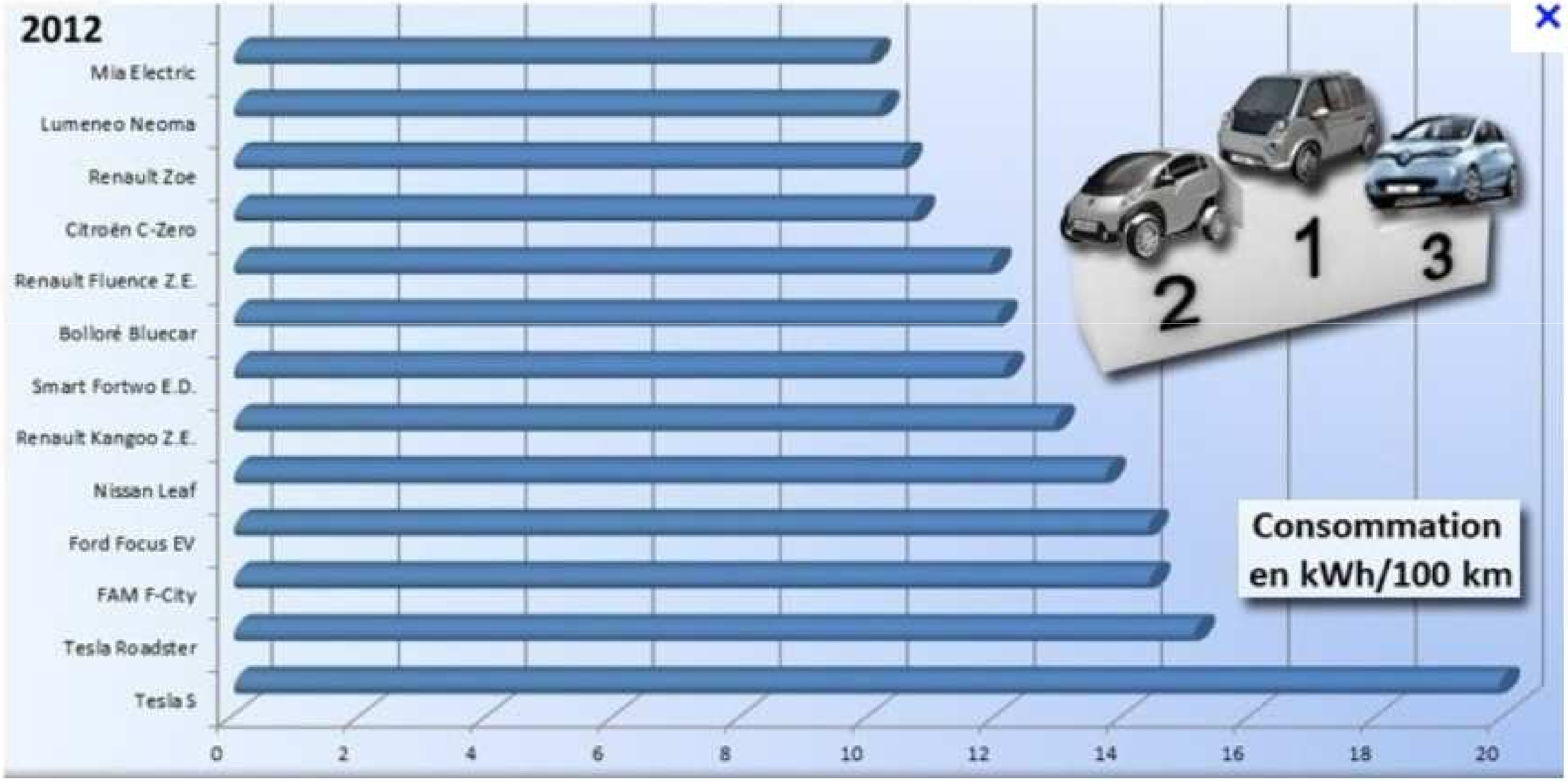
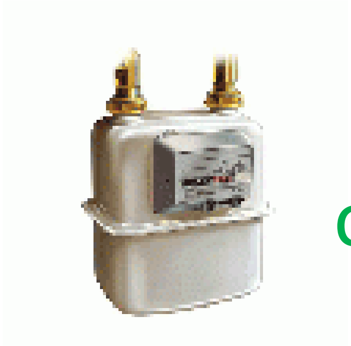
Efficiency of Electric Cars?
Mechanical needs/0.6?
Down to 10kWh/100km?



www.technologyvehicles.com



Gas?
or convert Gas to Electric First?

- Make first electricity with natural gas or use it directly?

Using CNG directly (compressed natural gas) in vehicles:

5% electricity so rather 9% gas equivalent to compress NG at 200 bar,

Fiat Punto http://www.cngas.co.uk/cngvehicles.php

3.9 kg/100km but 5% of energy in electricity to compress at 55% efficiency is 9% Nat. Gas is 4.25 kg gas

First convert gas to electricity?

1kg CNG = 45.86 MJ/kg LHV at 59%, 10% losses at night in distribution

24.35MJ electricity at wall plug

45.86*0.59*0.9/3.6=6.76 kWh/kg

An electric car needs about 10kWh/100km = 1.48kg CNG/100km

*Factor **2.87** longer distance,*

*But even **11.5** times if an ultralight EV of 2.5kWh/100km is used.*

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Some primary conclusions:

- **The worst electric car needs about the same prime energy than a conventional fuel cars. But possibly less CO2 if the electric energy mix is considered.**
- **Lightweight vehicles can do 10 times better in primary fuel and 20 times better in fuel cost/100km**
- **There is still room for optimizing classical cars in hybrid if it the total weight is also reduced.**

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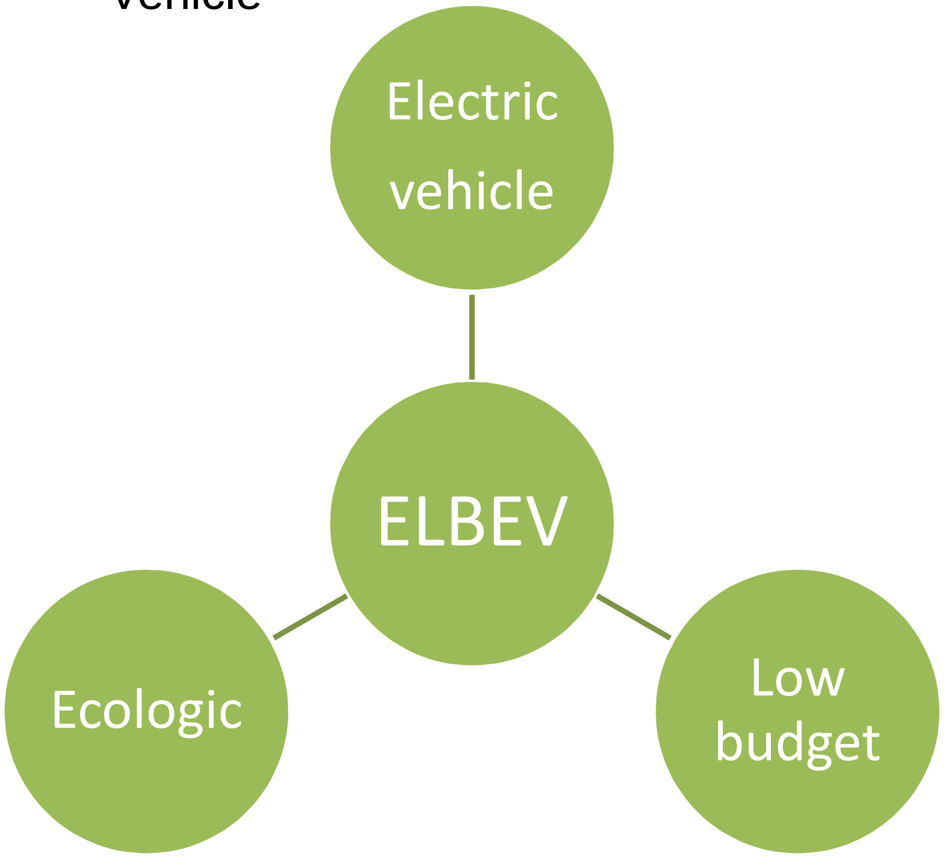
Part 2
Focus on ELBEV: “Ecologic Low Budget Electric Vehicle”

Research project

Ecologic Low Budget Electric Vehicle



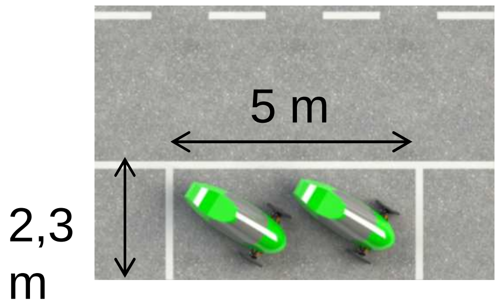
ELBEV

WHAT ?

- Electric single person vehicle, mainly for commuting purposes
- Three wheels
    - One rear
    - Two driven and steering front wheels
- Curb weight ±100 kg
- Maximum speed 70 km/h
- Range ±100 km
    - City and suburbs

DIMENSIONS

- Total length 2200 mm
- Total width 1200 mm
- Total height 1300 mm



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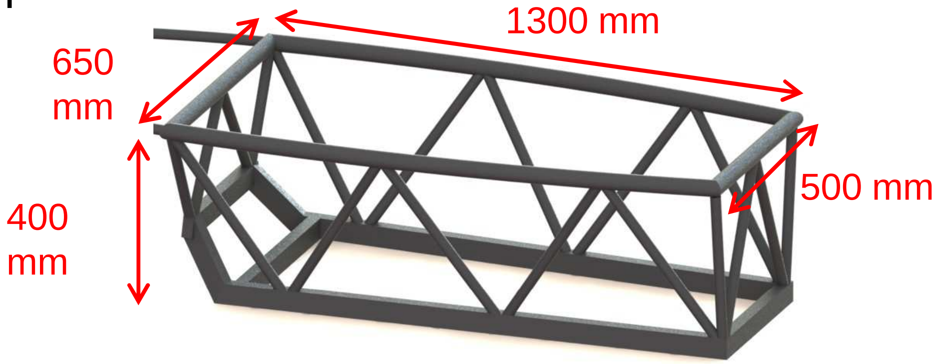
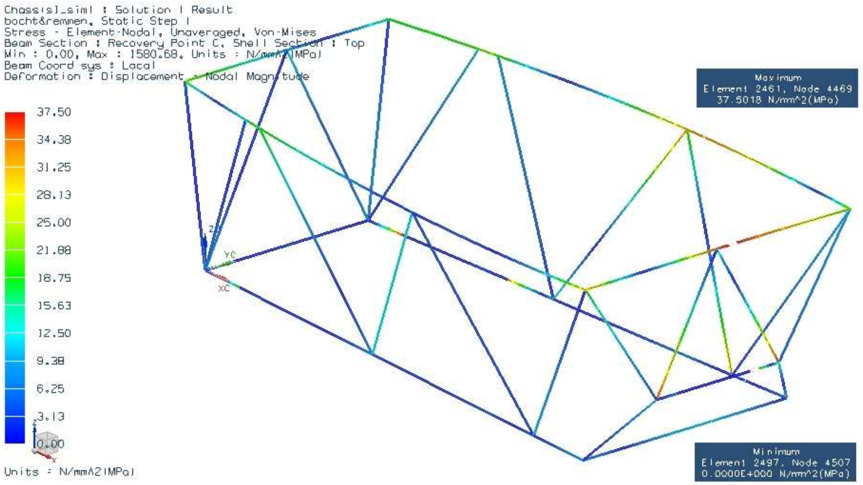
Chassis

- Aluminum 6060 T6 ($\sigma_{MAX.}$ = 35,55 N/mm²)
- Total weight: 10 kg
- Finite elements analysis using NX Nastran

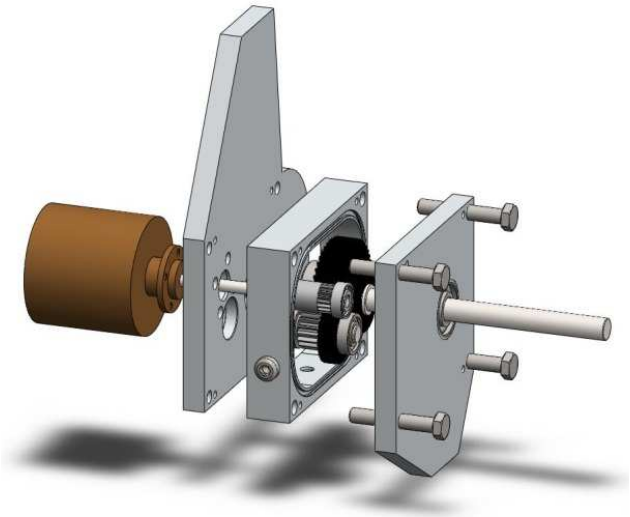


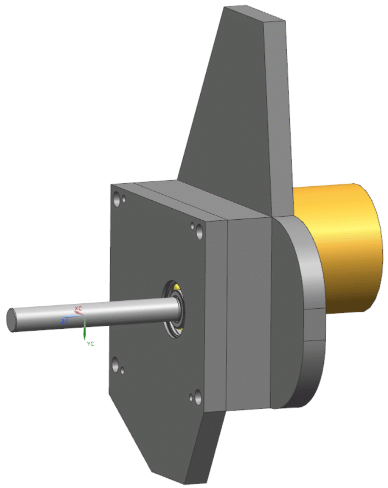


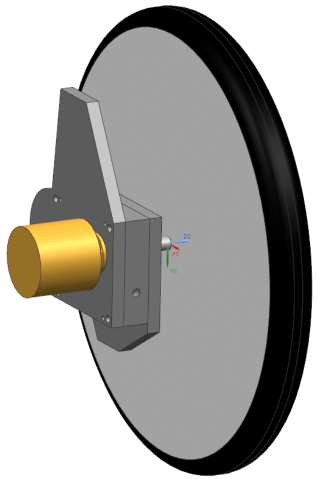
Reduction gear

- Drive and swivel shaft
- Motor:
    - o Outer rotor permanent magnet synchronous
    - o Brushless DC
- Two stage gear, later single stage

- Total weight (including motor): actual: 5,9 kg
  but still can be made lighter

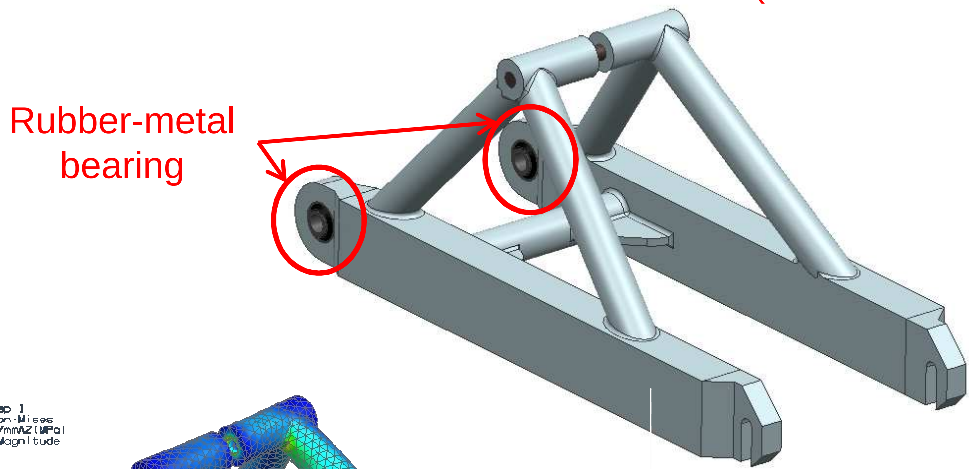


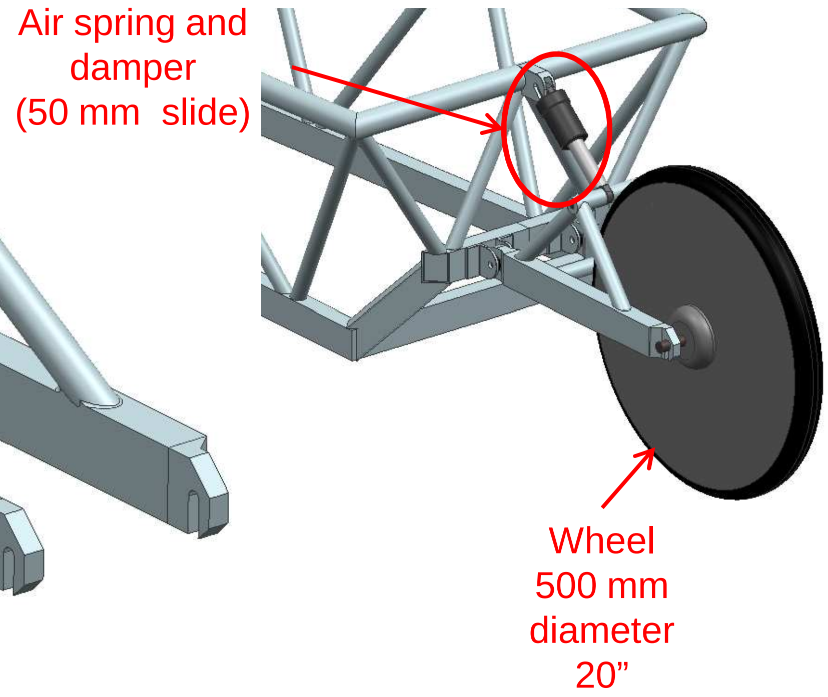


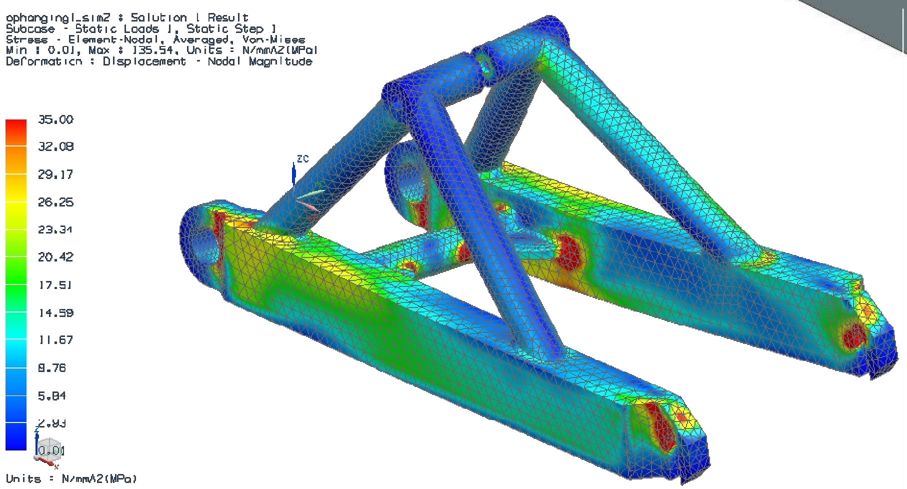


Rear suspension

- Aluminium 6060 T6 ($\sigma_{MAX.}$ = 35,55 N/mm²)
- Total weight: 1,7 kg
- Finite element analysis with NX Nastran

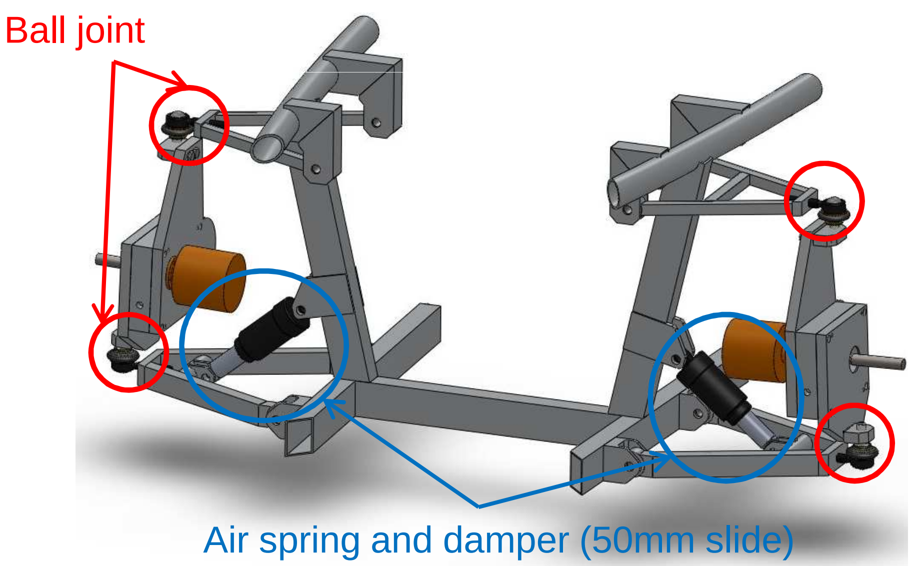


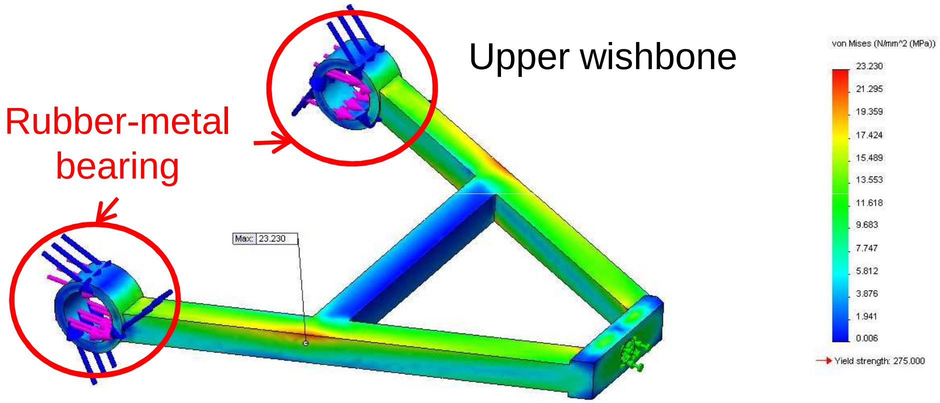


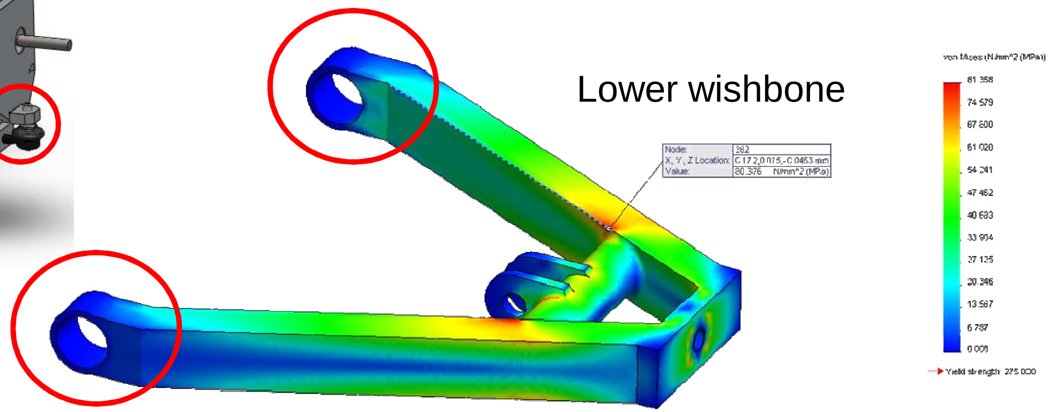


Front suspension

- Aluminum 6060 T6 ($\sigma_{MAX.}$ = 35,55 N/mm²)
- Total weight: 2,5 kg
- Finite element analysis using Solidworks

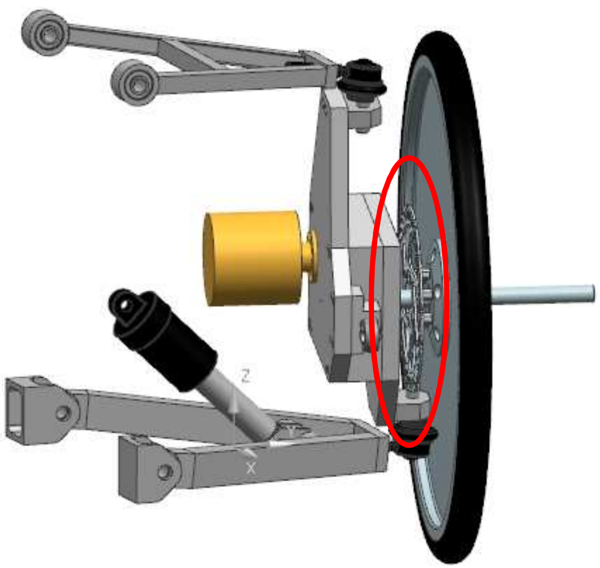




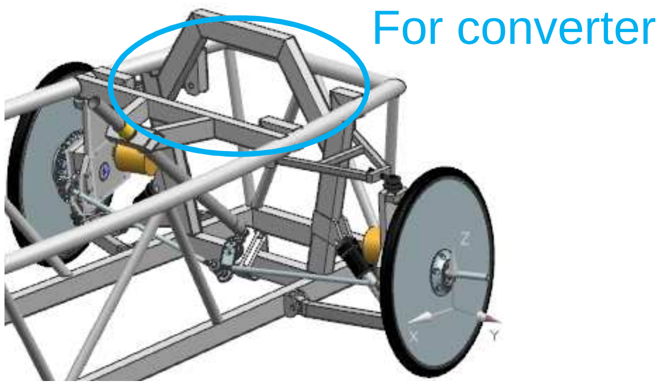


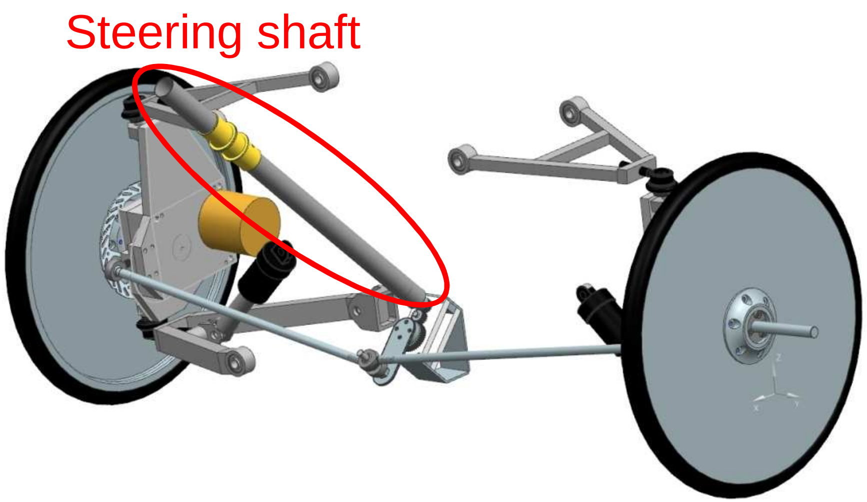
Brakes

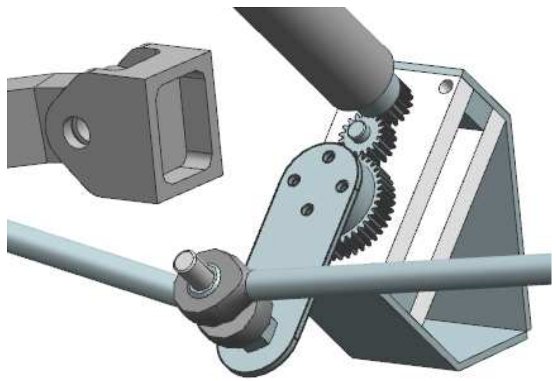
- Electric by handle on the steering bar
    - o Contactless gas and brake
- Mechanic by hydraulic brake (brake disc and claw)
    - o Rear wheel
    - o Each front wheel



Steering system







Batteries
+ battery management system

Batteries
- 2 battery packs of 48V (20Ah) in series

Cycle analyst
- Vehicle speed
- Odometer
- Electric information about the battery

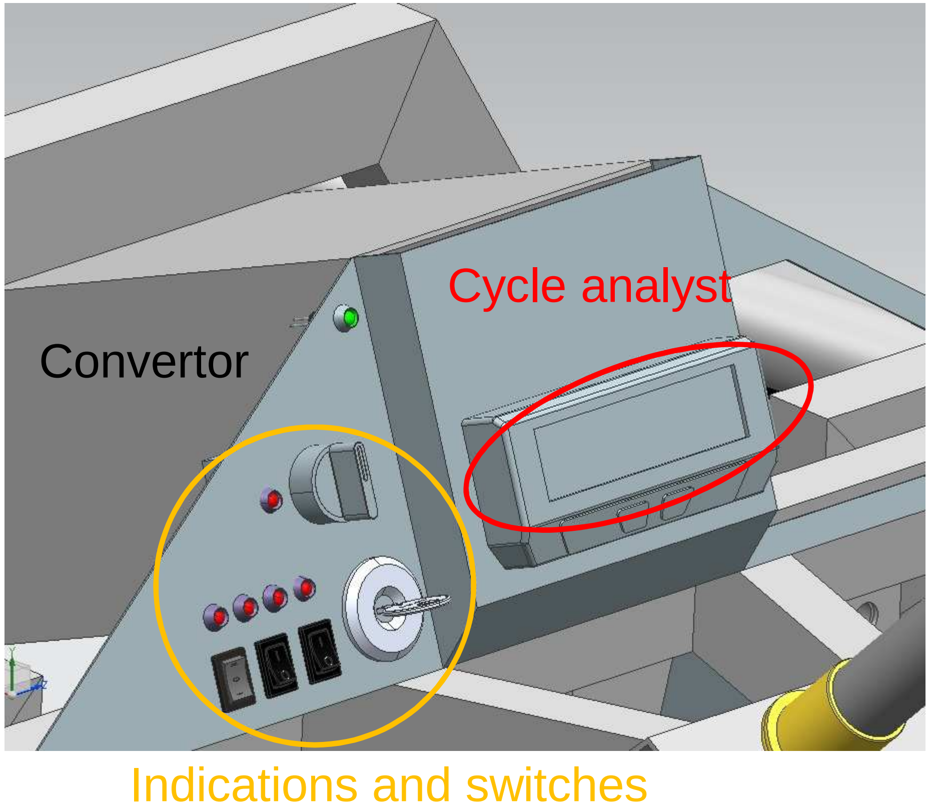
Battery

Cycle analyst

Battery charger

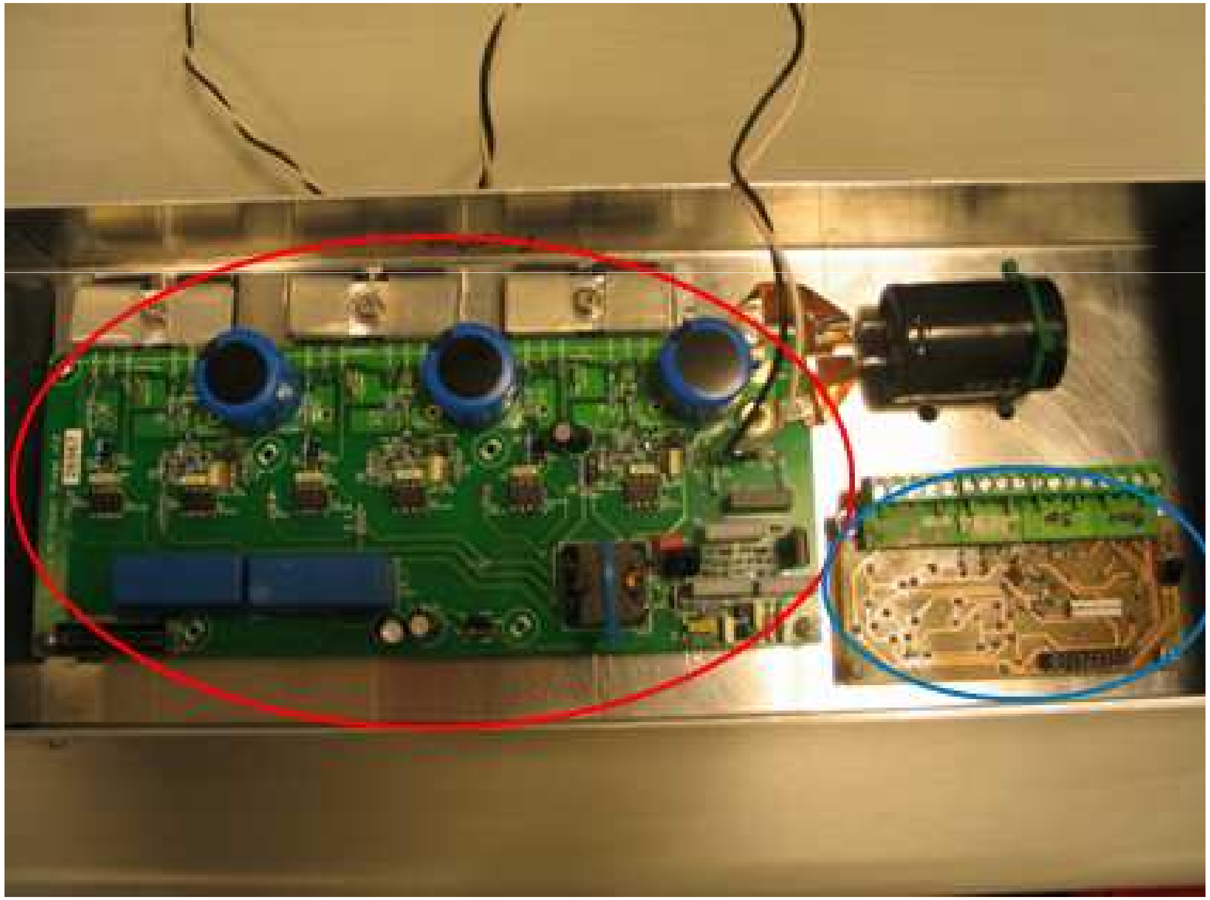
Dashboard

Is under construction



Convertor

Power stage

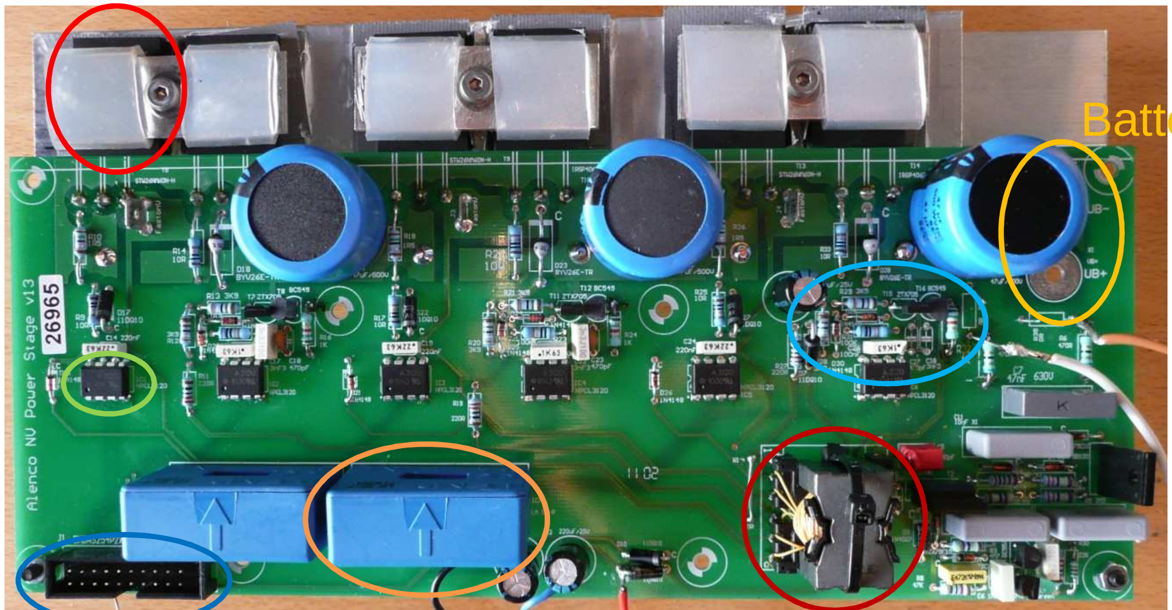


Control print

Convertor

Power print

- Three phase converter
    - o Torque control
    - o Quadrant selection



Converter

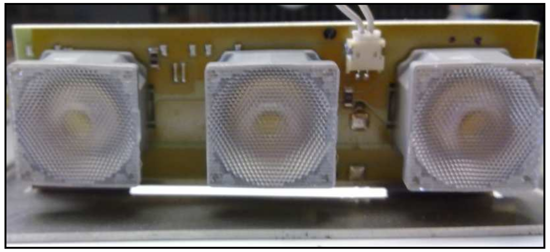
Control PCB

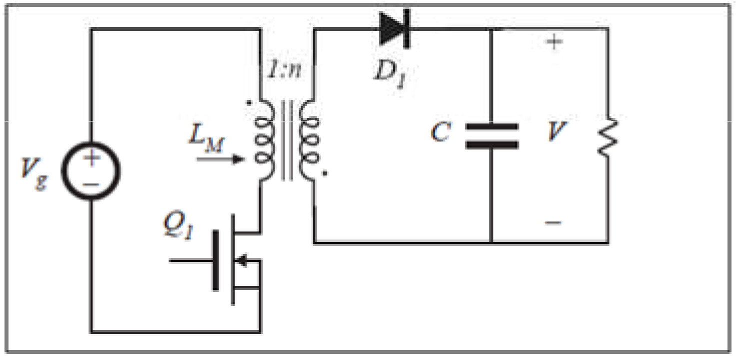
- Analog signals (brake- and gas handle)
  - o Drive
  - o Brake
- Digital signals
  - o Torque direction (forward – reverse)
  - o Enable (turn on- and off the BLDC)
  - o Hall sensors for the position
  - o Temperature protection for electronics
  - o Temperature protection for motor

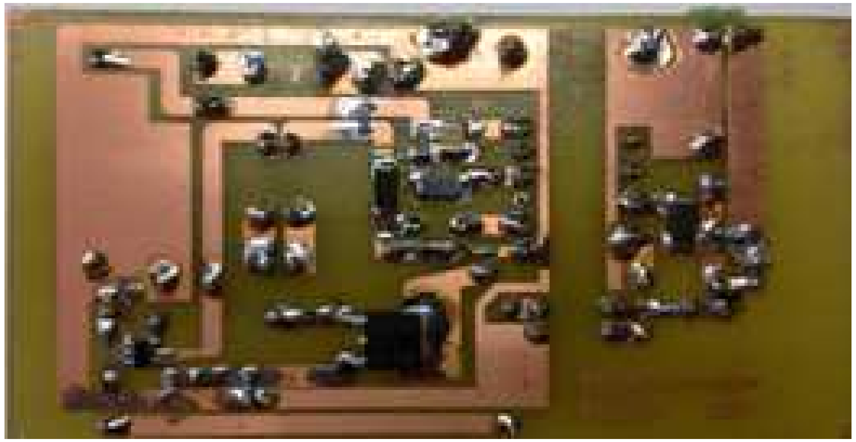
Motor and gear

Lighting

- Flyback converter
  - o Convert battery voltage(DC) to current for LEDs
  - o High efficiency
- LED lighting
- 12V supply for control







Body shell

•Body panels

o Bended plates (avoiding expensive molds)

• Lightweight

o Insulating shell

• Safety

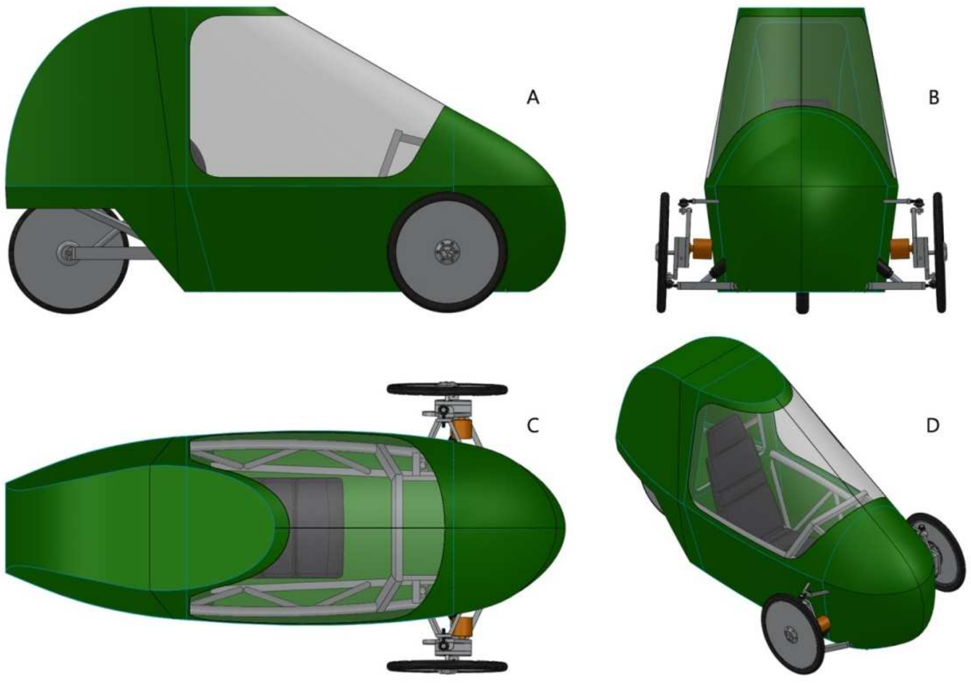
o Cage for driver

• Aerodynamics

• Canopy (get in- and out)

• Tax plate support

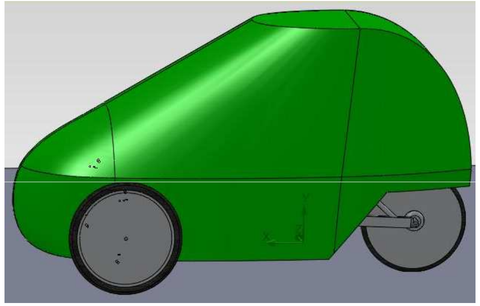
• Luggage space

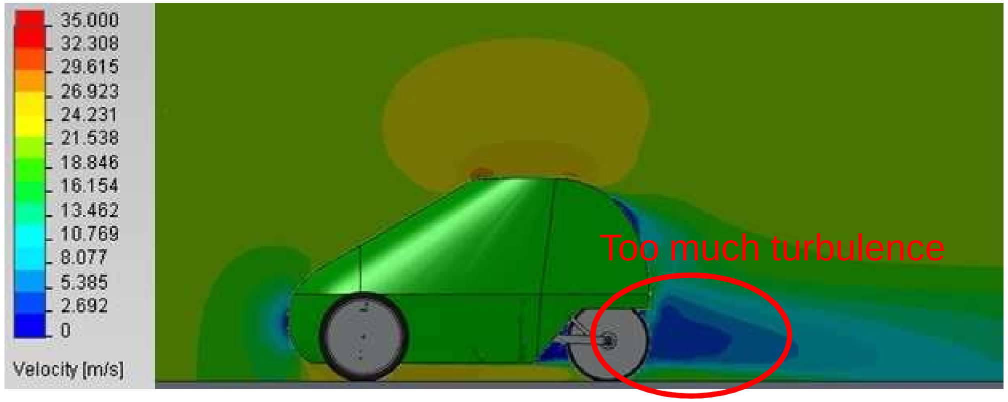


Aerodynamics

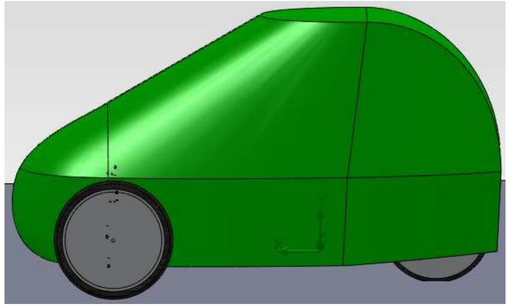
Influence of rear wheel cover

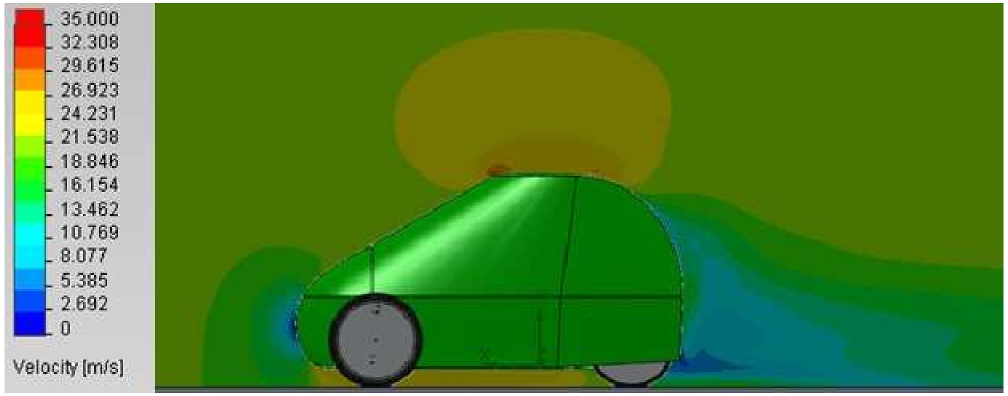
Model 1 body (Cd 0,32)





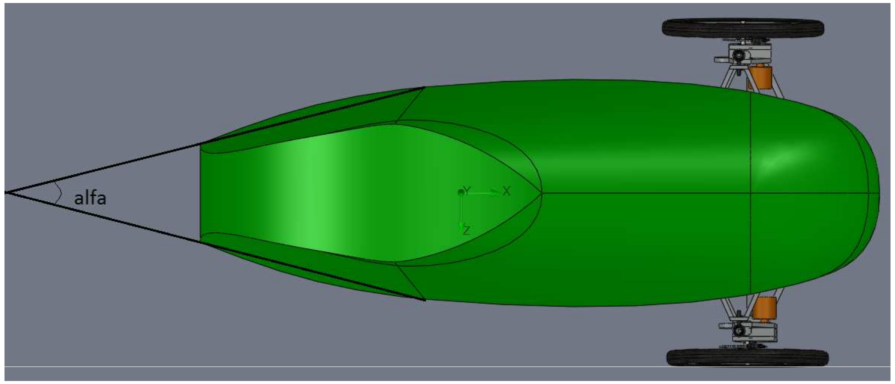
Model 2 body (Cd 0,28)

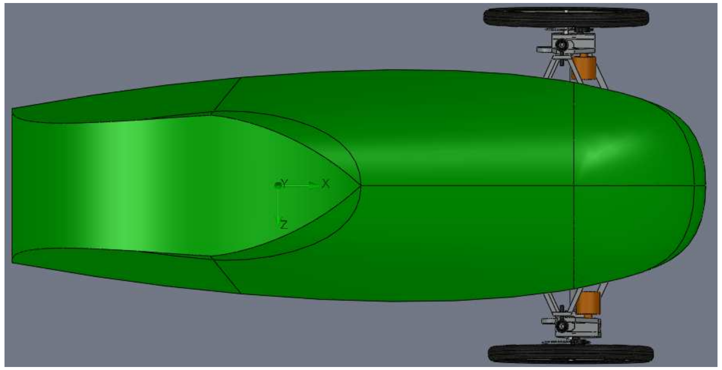


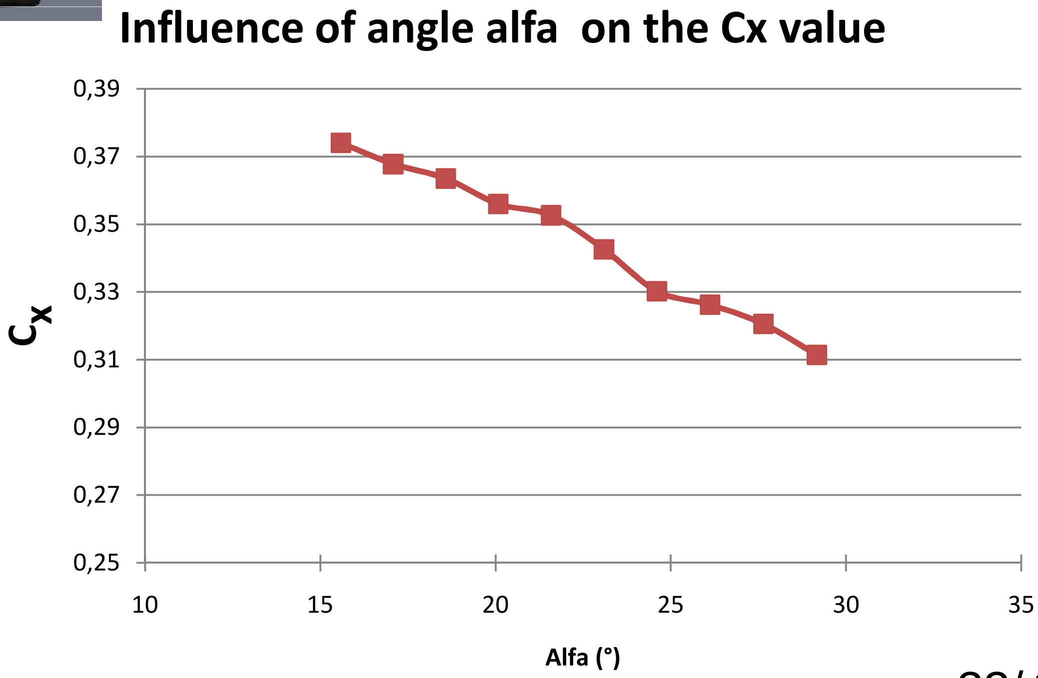


Aerodynamics

Influence of rear shape

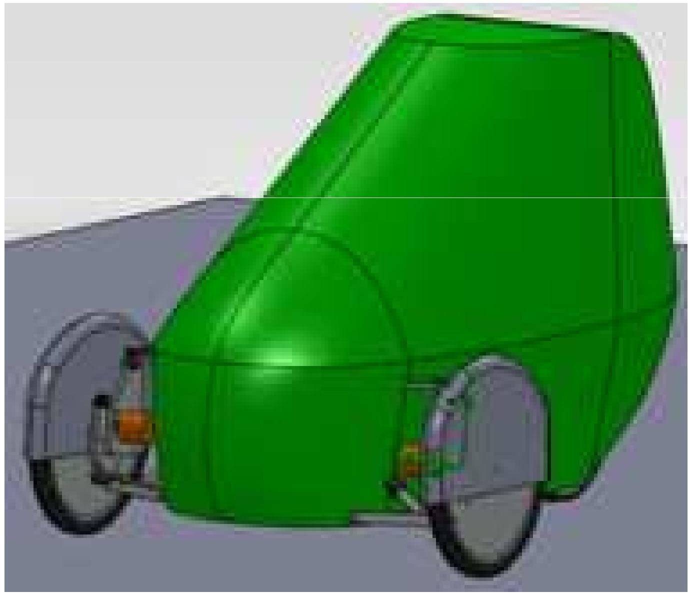


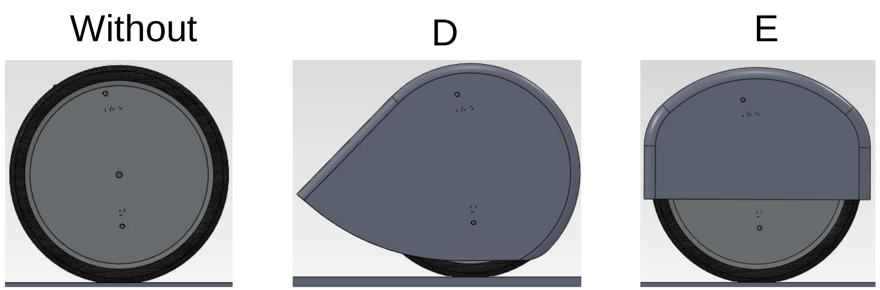


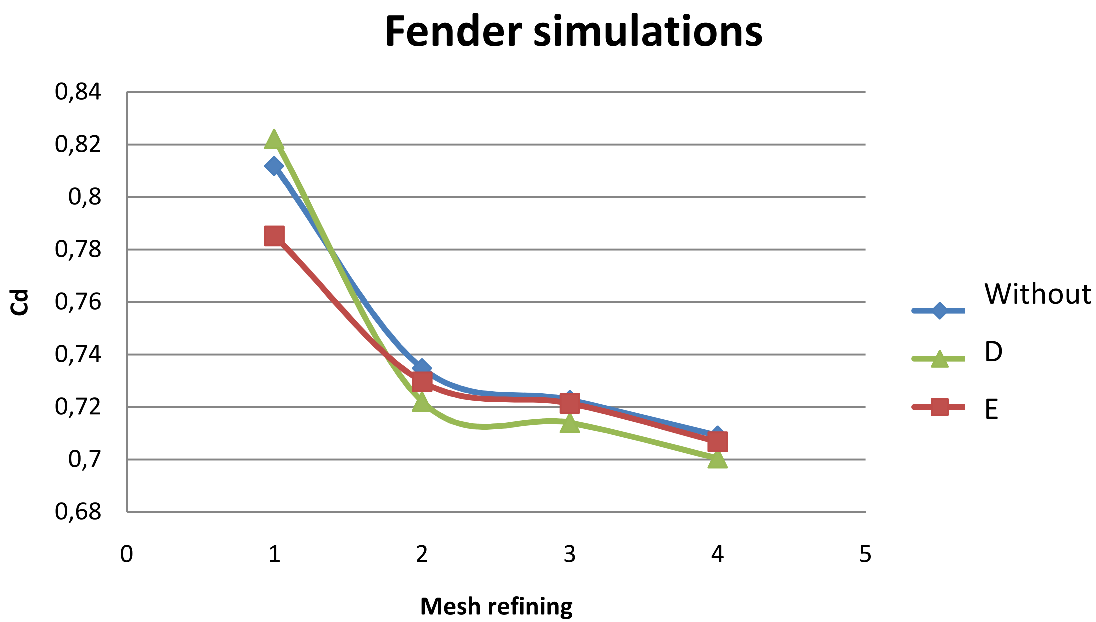


Aerodynamics

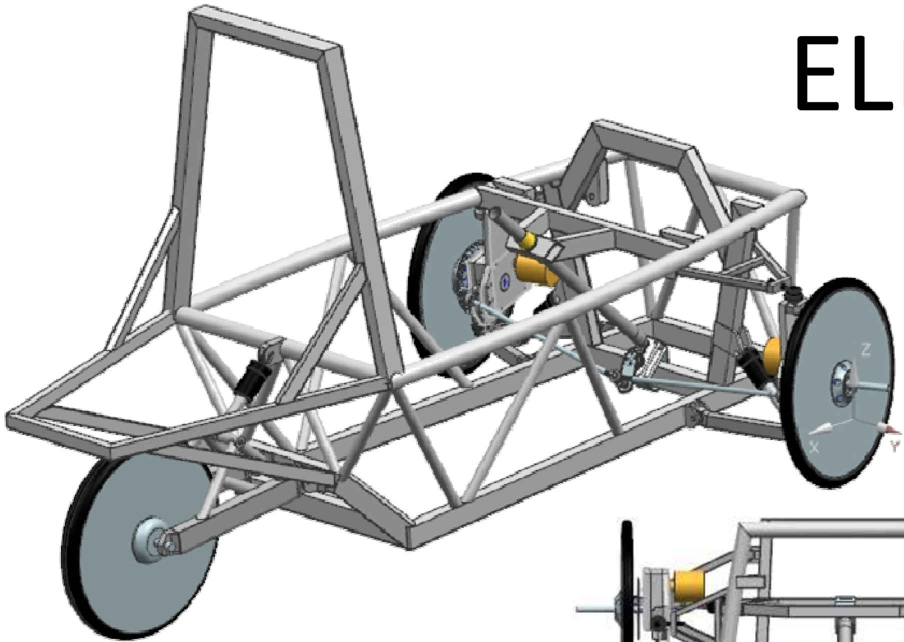
Fender optimisation of front wheels

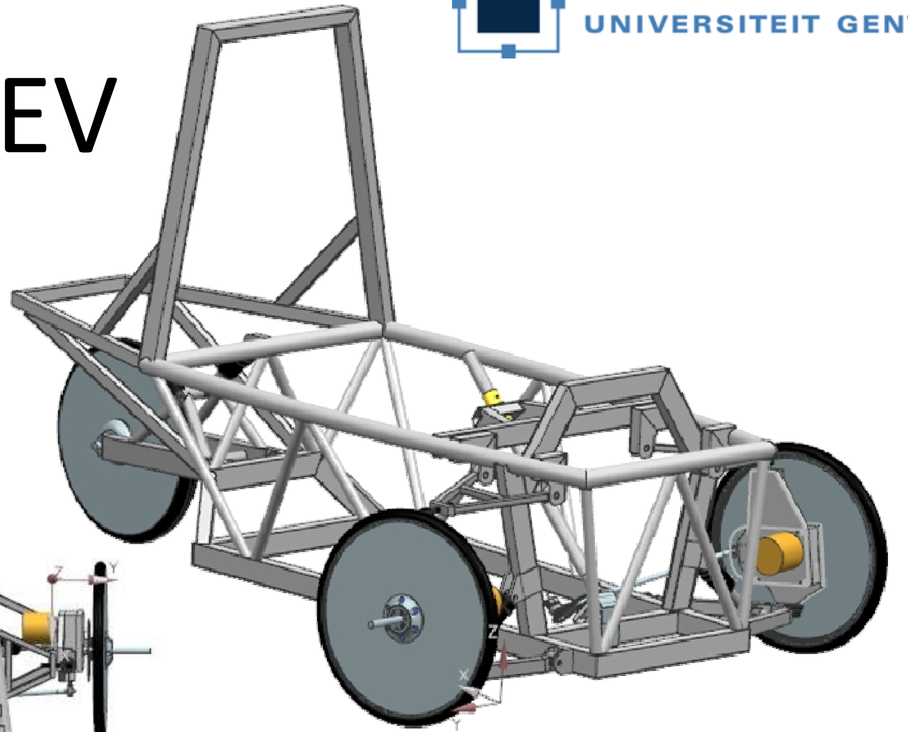




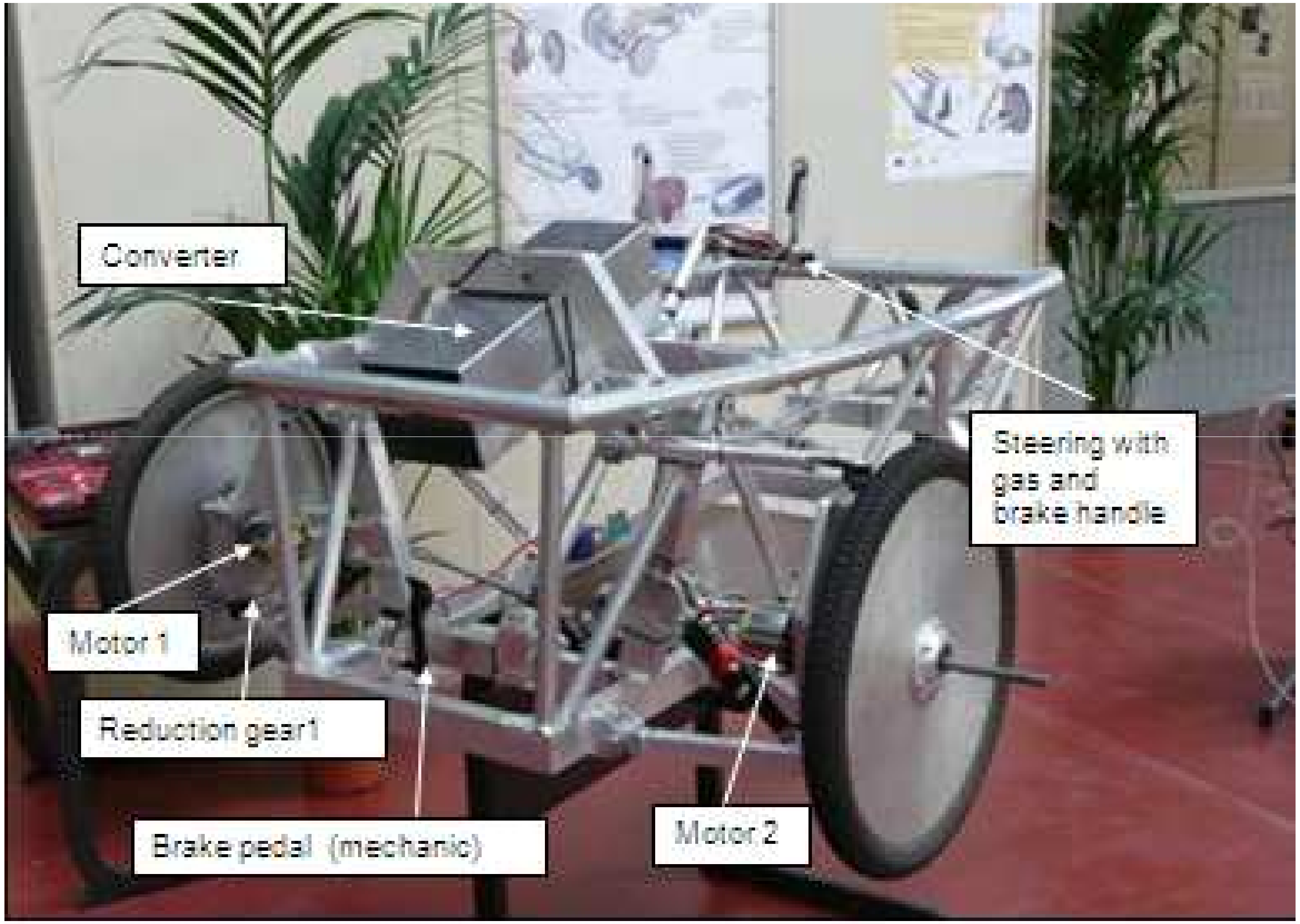


ELBEV





ELBEV



First prototype of "elbev"

ELBEV

Addendum:

Predicted performance (with results of a model in mathcad):

4000W peak power/motor, close to max. speed.
2000W maximal continuous power close to maximum speed.
1500W reference power/motor where the maximum efficiency is reached, at full speed.
90% maximal efficiency point of drive, about: 95% electric 97% converter, 98% max mechanic
90% battery efficiency at low current, but also an additional 0.1 ohm battery resistance is taken in account
10s time to reach 50km/h
200kg vehicle+driver mass
20Ah, 96V battery (=1.92kWh), larger batteries result in a longer range, but higher price.
3W auxiliary equipment (no light)

So, Losses include: Iron loss, Copper loss, conductors, wiring losses, equipment loss (no heating)

"Flat" C_{roll}= 0.01 , C_x= 0.3, A=0.9m^2
"Mountain" + also 25% time 6% climb, 25% time 6% down, 50% flat.
"City" Accelerate to listed speed each 1000m
With 2kWh/100km and a charger efficiency and of 90% 10000km/year one needs 2m^2 solar panel to compensate

ELBEV

Addendum:
Predicted performance:

"Flat"	C_{roll}= 0.01 , C_x= 0.3, A=0.9m^2
"Mountain"	+ also 25% time 6% climb, 25% time 6% down, 50% flat.
"City"	Accelerate to listed speed each 1000m

Ecologic footprint? With

- 3kWh/100km
- a charger efficiency and of 90%
- 10000km/year

one needs 3m^2 solar panel to compensate: can it be more renewable?

Problem: regulations stop the development?

- Homologation
- EMC
- Crash tests (NCAP) not yet active for motorbikes
- Testing?

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Addendum:
Predicted performance

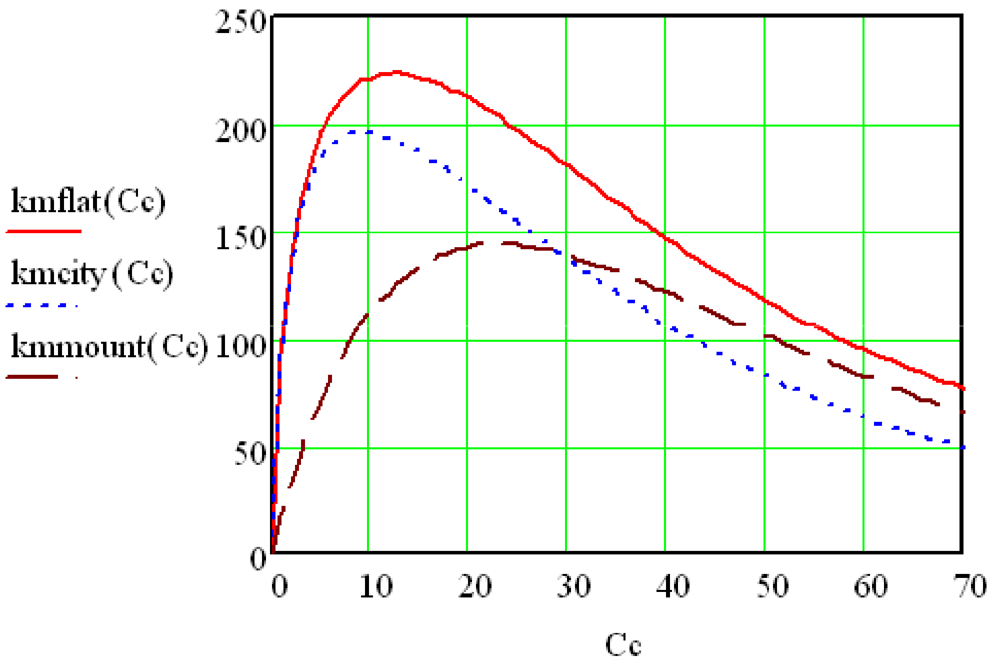

Fig. Predicted range as function of speed (in **km/h**) for different use, **3W** auxiliary

Note that:

- very low speeds are penalized by the auxiliary consumption
- very low speeds are not optimal at hill climbing.

ELBEV

Addendum:
Predicted performance

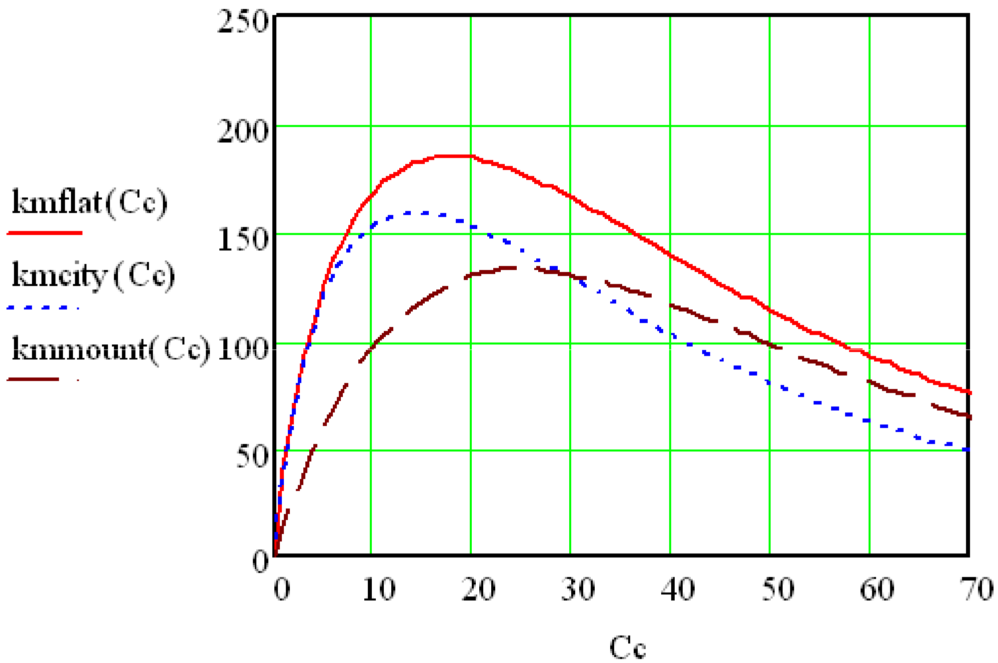

Fig. Predicted range as function of speed (in km/h) for different use, **30W** auxiliary

This means a heavy auxiliary consumption like wiper and light.
It reduces the range mainly below 30km/h.
This is the reason to use led lights and no separate 12V battery.

ELBEV

Conclusion:

- Ultralight electric vehicles are possible.
- They need a very low energy
- They still need investment and development
- They can help us to reach European 2020 and 2050 energy goals
  What about the world need?
- What are the limiting factors in society?